Blog - MEMS New Product Development, Importance of Product Validation, *David DiPaola, DiPaola Consulting, LLC, www.dceams.com*

Product validation is an essential part of all successful MEMS new product developments. It is the process of testing products under various environmental, mechanical or electrical conditions to simulate life in an accelerated manner. Testing early and often needs to be a daily routine and not just a popular phase used in meetings. This blog will cover proven methods to accurately perform MEMS product validation while mitigating potential issues resulting in repeated tests and non accurate results.

Measurement system analysis or MSA is a methodology to qualify the measurement system that will be used to characterize the product. In the context of MEMS, this could be a function test system for characterizing the performance of a MEMS pressure sensor by applying known pressures / temperatures and measuring sensor output. The first step of MSA is to calculate total system accuracy determined by a tolerance stack of subcomponent errors traceable to NIST reference standards. This will ensure your test system has the accuracy needed to properly characterize the samples. In addition, system linearity of the true and measured value with minimal bias change and stability of the measurement system over time should be demonstrated. Lastly, a Gage R&R (using average and range or ANOVA methods) in percent of process variation (not tolerance) should be completed to demonstrate repeatability and reproducibility for each test system utilized. An excellent reference for MSA is aiag.org, Measurement System Analysis.

Verification of the test system setup and function of the equipment is an important step prior to the start of validation. Often times, improper test set up or malfunctioning equipment results in repeated tests and delayed production launches. This is easily avoidable by documenting proper system setup and reviewing the setup thoroughly (every parameter) prior to the start of the test. Equally important, the engineer should verify the system outputs are on target using calibrated tools after the tools themselves are verified using a known good reference.

We all like to believe that customer specifications are well thought out and based on extensive field and laboratory data. Unfortunately, this is not always the case. Hence it is prudent for engineers to challenge areas of the customers' specifications that do not appear robust. Neither the customer nor the supplier wins if the product meets the defined specification but fails in the field. The pain of such events is pervasive and extremely costly for all parties. As parts complete laboratory tests, take the added step of comparing the results to similar products in the field at the end of life and ensure similar degraded appearance. When ever possible, test products to failure in the laboratory setting to learn as much as possible about failure mechanisms. When testing to failure is not possible, perform the validation to 3 - 5X the customer specification to ensure proper margin exists mitigating the risk of field failures. Furthermore, always take advantage of field tests even if limited in duration. They can provide valuable information missed in a laboratory validation.

As briefly stated earlier, a function test or product characterization is the process of applying known inputs such as pressure, force, temperature, humidity, acceleration, rotation, etc. (sometimes two or more simultaneously), measuring the output of the MEMS product and comparing it to the desired target. This is completed to ensure the product is compliant with the stated performance specification from the manufacturer. As product life is accelerated through the validation, the device function should be characterized multiple times during the test to understand product drift and approximate time of failures. It is recommended to perform function tests 3 - 8 times at periodic (equally spaced or skewed) intervals during the validation after the initial pretest characterization. As an example, I often test products at intervals of 0, 25, 50, 75 and 100% of the validation.

Use of test standards is highly encouraged as it brings both consistency and credibility to validations performed. Several organizations develop test standards for general use such as

ASTM, JEDEC, AEC, Military and more.   When a product is tested to standards widely excepted in the industry, the intended audience is more likely to accept the results than if a non-familiar possibly less stringent test method was applied. Some commonly used standards include ASTM B117 (salt spray), JEDEC JESD22-A106B (thermal shock), Automotive Electronics Council AEC-Q100 (stress test for integrated circuits) and MIL-STD-883 (various environmental tests) just to mention a few. A list of validation standards used across the MEMS industry can be found in the MEMS Industry Group Member Resource Library, *Standards Currently in Use at MEMS Companies*.

In the validation of MEMS products, it is tempting to perform the testing on units from one wafer that has yielded 1000 pieces. However, this is a single window in time and does not properly reflect the true process variation that can occur. A better sampling approach for validation is taking units from multiple wafers within a lot and across multiple wafer lots. Equally important, differing raw material lots should be used (one example is the starting SOI wafers). This will ensure supplier, equipment, process, operator and time sensitive factors are well understood.

Controls are another method to learn valuable information about the products being validated and the equipment being used. A basic control could be as simple as a product that is function tested at each stage of the test, but does not go through any of the validation (i.e. sits on a shelf at room temperature). This will give an indication if something has gone wrong with your test system should the same errors be seen in both experimental (parts going through validation) and control groups. Another use of a control is testing a product that has previously passed a given validation (control group) while simultaneously testing a product that has under gone a change or is entirely new (experimental group). This will provide information on whether the change had any impact on the device performance or if the new device is as capable as a previous generation.

Lastly validation checklists are a valuable tool to ensure each test is set up properly before the test begins. Without the checklist , it is easy to over look a step in pursuit of starting the test on time to meet a customer's schedule. Below is a sample validation check lists for thermal shock. This can be modified for other tests as well.

Thermal Shock Validation Checklist

- Perform proper preventative maintenance on the environmental chambers before the start of the test to prevent malfunction during the test
- Identify appropriate control and experimental groups and ensure proper sampling from multiple wafers and lots
    - Document sample sizes
- Identify a proper validation standard or customer specification to define the test
- Document pass / fail criteria for the devices under test
- Create a test log and record any time an event occurs (i.e. start of test, end of test, devices removed from thermal chamber for testing, etc.)
- Verify calibration of measurement reference and trace it back to a national standard
- Verify the measurement reference with appropriate simple test. (i.e. thermal couple’s accuracy and repeatability with boiling water, room temperature, ice water and other known sources)
- Measure the temperature of the hot and cold chambers with an accurate and verified reference prior to the start of the test (i.e. thermal couple ± 1°C)
    - Verify chamber temperature is consistent across the part loading
- Verify the time it takes the thermal load to reach the desired temperature (i.e. -40°C) and that its within test guidelines
- Measure the transition time between hot and cold chambers and verify its within test guidelines
- Complete all necessary MSA on test equipment and document the results
- Engrave serial number on each device (paint pen can be easily removed)
- Document the location of devices in environmental chamber with digital photograph

- Record serial number and manufacturer for environmental chambers used
- Determine and document periodic intervals for device function test
- Continuously monitor environmental chamber temperature for the duration of the test using an appropriate chart recorder
  - Document location of thermal couple (photo) and verify it is located close to parts
- Monitor device output continuously during the test
- Check on the environmental chamber daily to ensure no malfunctions have occurred and monitor daily cycle count
- Create a test in process sign with appropriate contact information for support staff
  - This will likely prevent individuals from accidentally turning off the environmental chamber or changing temperature profiles without notifying you
- Document any changes to this specification for future reference

Product validation is a critical tool to learn about MEMS performance over a laboratory based accelerated life. Its an excellent method to validate theory and ensure product robustness in the field. The due diligence presented in this blog will help engineers avoid seemly small mistakes that cause repeated tests, inaccurate results and missed customer deadlines.

Bio:

David DiPaola is Managing Director for DiPaola Consulting a company focused on engineering and management solutions for electromechanical systems, sensors and MEMS products. A 17 year veteran of the field, he has brought many products from concept to production in high volume with outstanding quality. His work in design and process development spans multiple industries including automotive, medical, industrial and consumer electronics. He employs a problem solving based approach working side by side with customers from startups to multi-billion dollar companies. David also serves as Senior Technical Staff to The Richard Desich SMART Commercialization Center for Microsystems, is an authorized external researcher at The Center for Nanoscale Science and Technology at NIST and is a Senior Member of IEEE. Previously he has held engineering management and technical staff positions at Texas Instruments and Sensata Technologies, authored numerous technical papers, is a respected lecturer and holds 5 patents. To learn more, please visit www.dceams.com.